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Patentanmeldung Nr. Patent application No. Demande de brevet n°

03101664.5 ✓

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Antenna arrangement for wireless headphone applications

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## Antenna arrangement for wireless headphone applications

The invention is related to a wireless digital headphone system. This headphone system may conform to the new European cordless audio standard EN301 357. This standard preserves the 863-865 MHz frequency band for wireless audio applications. In the US the 902 to 926 MHz ISM band may be used.

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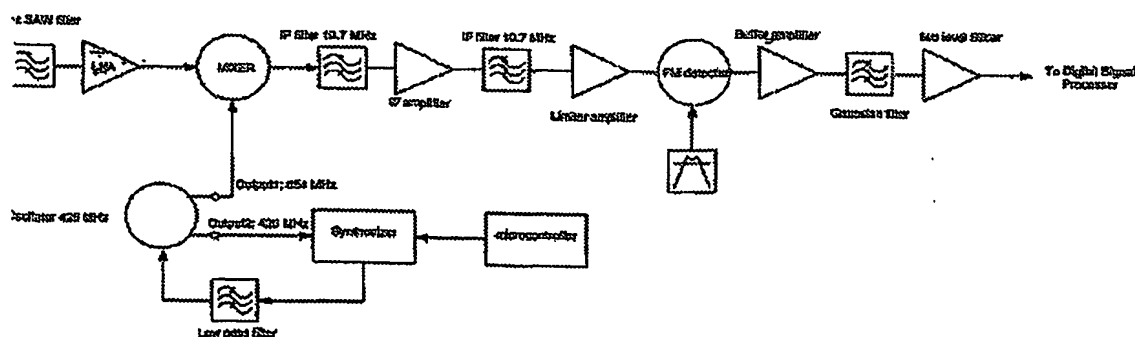
The wireless digital headphone system comprises a base station and a headphone. Audio signals from DVD, TV and other sources are Dolby ACS processed at the base station. The generated data stream is GFSK (Gaussian Filtered Frequency Shift Keying) modulated at 864 MHz (or 914 MHz for the US). The digitally modulated RF signal is amplified to the legal

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power limit and transmitted by an antenna. A digital receiver in the headphone captures the transmitted RF signal from one of its antennae (the headphone may also be equipped with a single antenna). The received RF signal is FM demodulated in the receiver unit. The demodulated signal is converted into a

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digital data stream. A digital signal-processing unit processes the data stream. Finally the digital audio stream is converted to analogue and amplified by the headphone amplifier.



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Figure 1

The receiver as shown in Fig. 1 is equipped with antenna-diversity (ADU) and estimates the best antenna by means of error detection in the DSP unit. A SAW filter is blocking the out-of-band signals (Bandwidth = 10 MHz) and reduces leakage of the oscillator (and harmonics) to the antenna. The RF signal is passing through the SAW filter, centered at 864 MHz (or 914MHz for the US), and is amplified by a low noise amplifier. This amplifier sets the sensitivity (and the operating range) of the receiver while isolating the oscillator from leaking into the antenna. The RF signal is then down converted to 10.7 MHz Intermediate Frequency by a synthesized local oscillator. This local oscillator has two outputs, one for the mixer input and one for the synthesizer input. The down converted IF signal is passed through two IF filters and an IF amplifier. The filters are there for the selectivity of the receiver (Selecting the wanted transmitter, bandwidth = 300 KHz). The filtered IF signal is then amplified, limited in amplitude and FM demodulated in a standard FM radio IF IC. The FM demodulated signal is Gaussian filtered and converted to a digital data stream by the slicer circuit. The data rate ranges from 230 to 380 kbps or even higher. The DSP unit further processes the digital data stream.

A strong RF signal from the transmitter (i.e. the base station) has to be captured by the receiver in the headphone to provide a comfortable operating range for the customer. This can be done with a good antenna arrangement. The problem is that the mechanical dimensions are limited in a headphone. The known antennas have electrical sizes of 0.25 to 0.5 of the wavelength. A second problem is that the majority of the known antennas have a relatively small bandwidth. Any detuning of the antenna will result in attenuation of the received signal strength. This is exactly what happens in a headphone application since the human head is nearby the antenna.

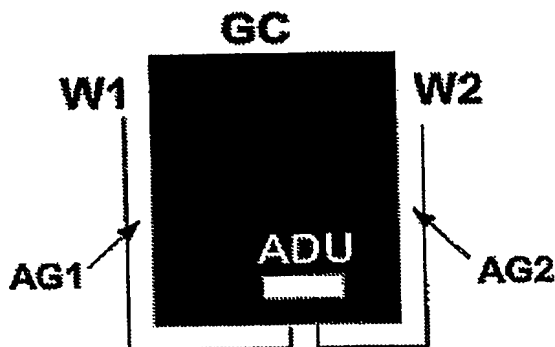


Figure 2

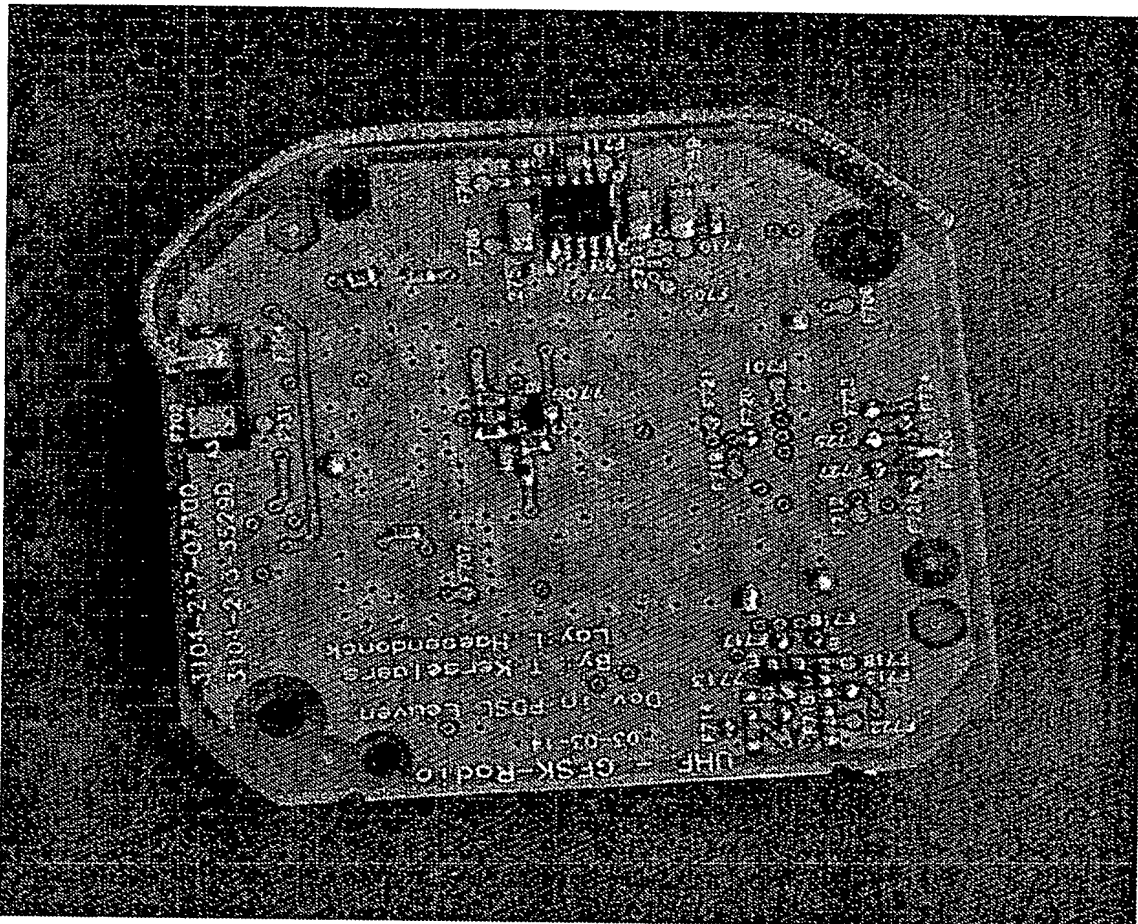
In order to solve this problem a novel antenna arrangement is used that fits into the mechanical constraints of a HiFi headphone and that is able to capture RF signals with good effectiveness. The antenna arrangement consists out of a ground conductor (GC), parallel to the head. It is found that such an antenna plane close to the head acts as a magnetic loop. The transmitted RF signal is introducing RF currents into the ground conductor (GC). To enable the ground conductor to function as an antenna two coupled conductors (W1 and W2) are separated with an air gap (AG1 and AG2) from the ground conductor (GC). A first air gap (AG1) is separating a first conductor (W1) that is substantially in the same plane of the ground conductor (GC). The first conductor (W1) couples a first part of the received signal by the ground conductor (GC) to the first input of the antenna-diversity unit (ADU). A second air gap (AG2) is separating a second conductor (W2) that is substantially in the same plane of the ground conductor (GC). The second conductor (W2) couples a second part of the received signal by the ground conductor (GC) to the second input of the antenna-diversity unit (ADU). The DSP unit in the receiver will select one of the two antenna inputs according measured bit error rate criteria or best signal noise ratio of the received RF signal.

It is found that this antenna arrangement performs nearly as well as a dipole antenna construction and this in combination close to the human head. The antenna arrangement has a broad operational bandwidth in contrast with most known antennae while providing antenna diversity.

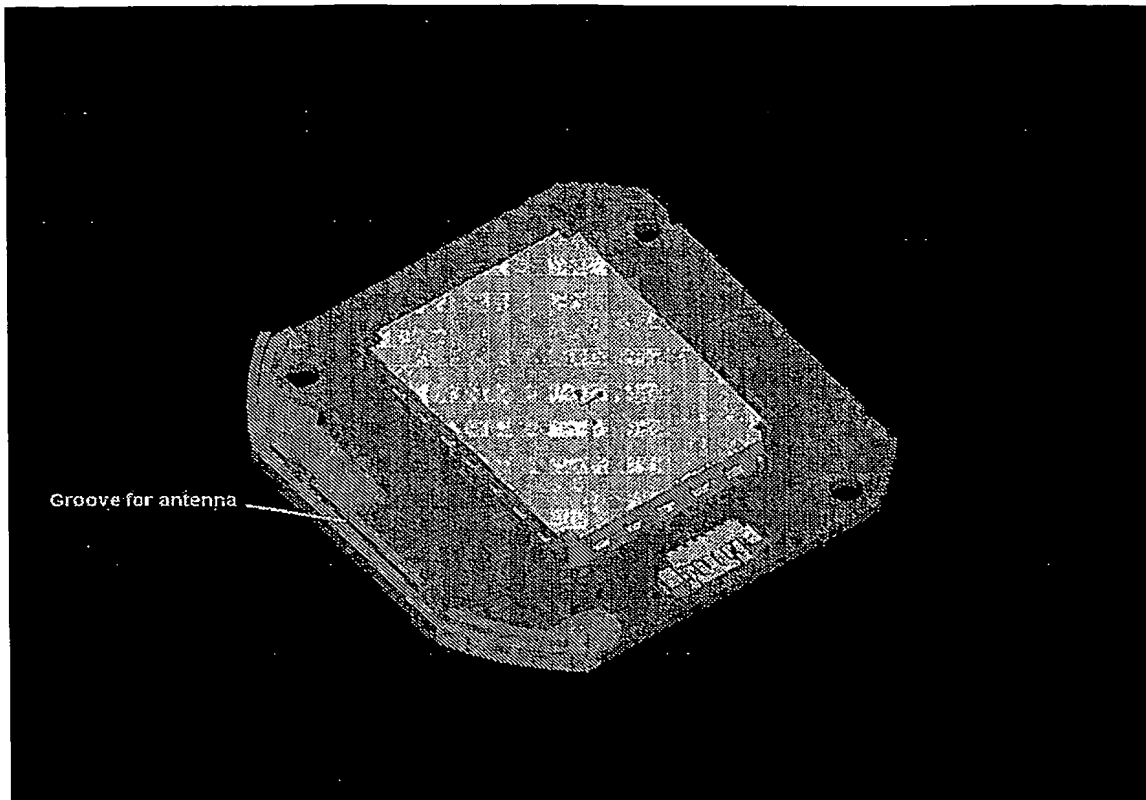
The ground conductor is advantageously the printed circuit board with the receiver electronics. Good results are obtained when the printed circuit board is approximately 90% covered by a solid copper ground area. Matching of the antenna or antennae can easily be done at the ends of the coupled wire or wires. The ground conductor, coupling conductors length and air gap, can tune resonant frequency of each antenna. The Ground conductor approaches the electrical dimensions of 0.25 wavelength. It is found that tuning, matching and operational bandwidth can be controlled very easily by the gap dimensions and the length of the conducting wires.

It is also possible to use only a single conductor (W1 or W2) that is separated from the ground conductor (GC) by an air gap (AG1 or AG2) and that is substantially in the same

plane of the ground conductor (GC) in the antenna arrangement. See below for an example with a single wire that is fitted to the edge of a printed circuit board.



Alternatively, the antenna wire may be included in a holder that is attached to the printed circuit board as shown below.



- The antenna-coupling conductors can also be implemented by copper traces on the printed circuit board. Another advantage is that, unlike other full size antennas, there is not much influence by other electronics that is nearby the antenna arrangement. In this antenna arrangement the ground conductor may comprise the receiver electronics, e.g. when a multi-layer printed circuit board is used.
- 10 As an example measurements are made for a digital wireless headphone. The ground conductor contains the RF circuitry of the receiver. The down converter is enclosed in a metallic container connected to the printed circuit board (pcb). The coupling conductors are parallel wires with the printed circuit board. The parallel wires are substantially in the same plane as the printed circuit board and are separated by an air gap of 3 mm. The dimensions of the pcb are 53 by 64 mm. The pcb is 4-layer construction in FR4 material. The operating frequency of the antenna arrangement in this example is 876 MHz. An advantage is that, unlike other full size antennas, there is not much influence by other electronics on the printed circuit board.
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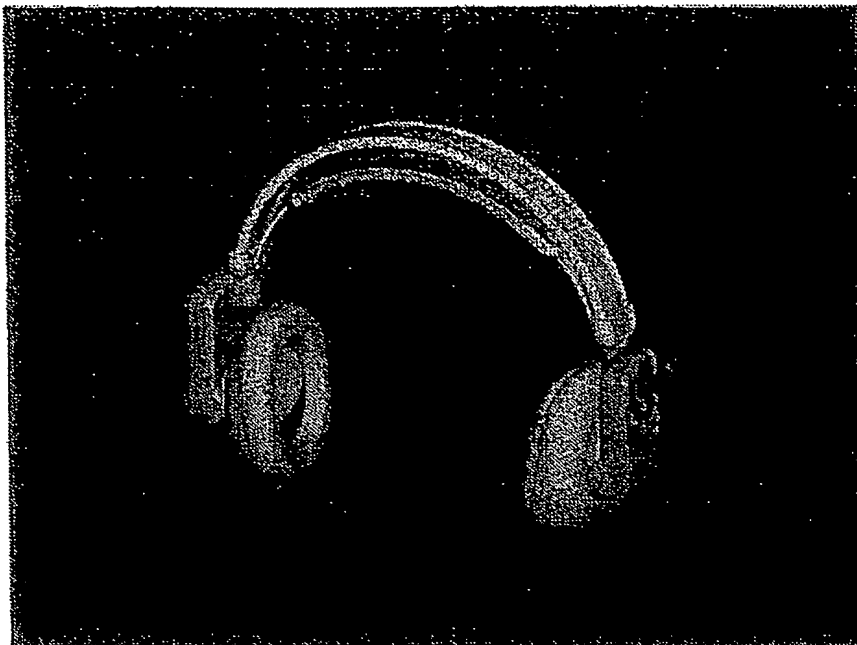


Figure 3

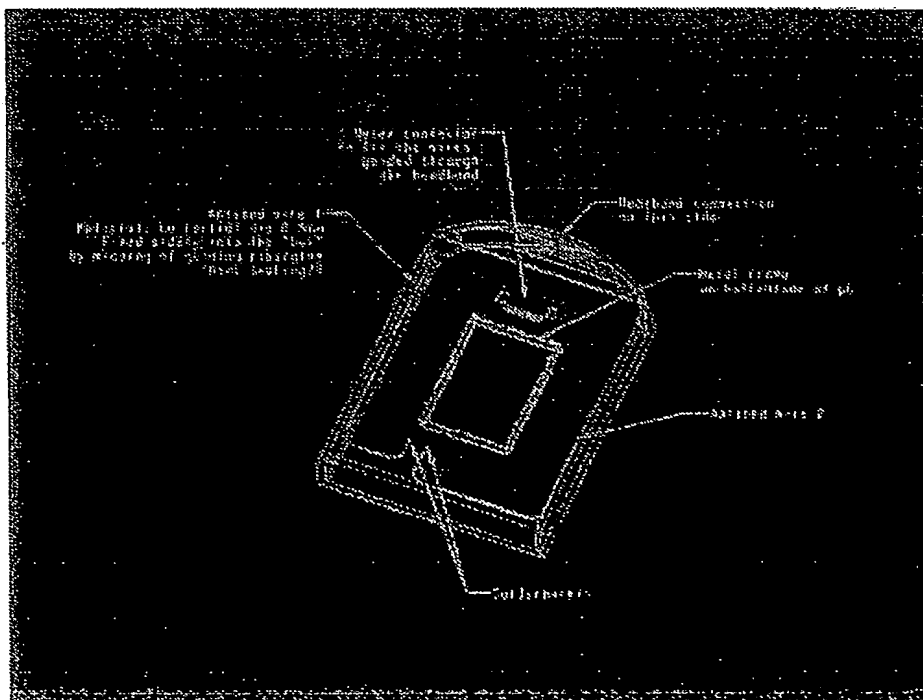


Figure 4

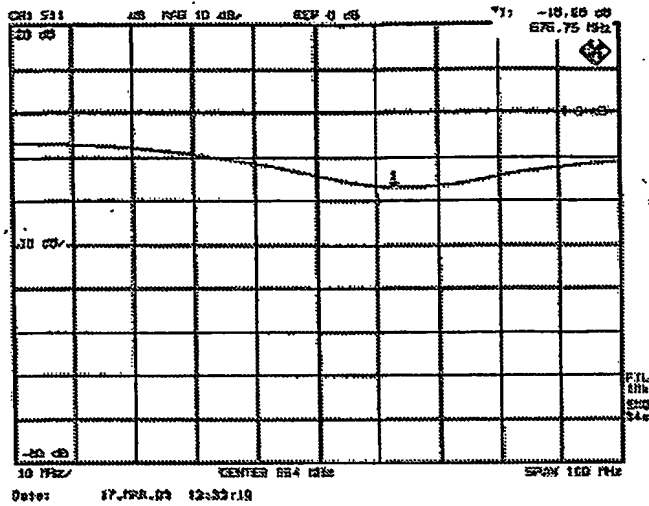


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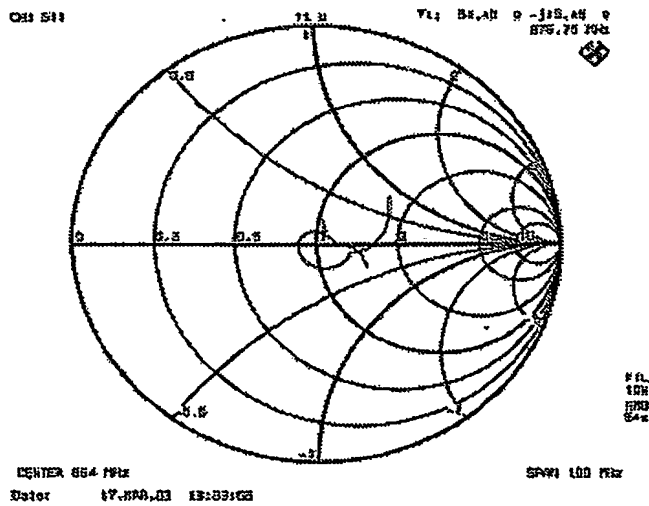
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antenna 1: Return loss measured on W1 coupling conductor



Antenna 1: Impedance measured on W1 coupling conductor



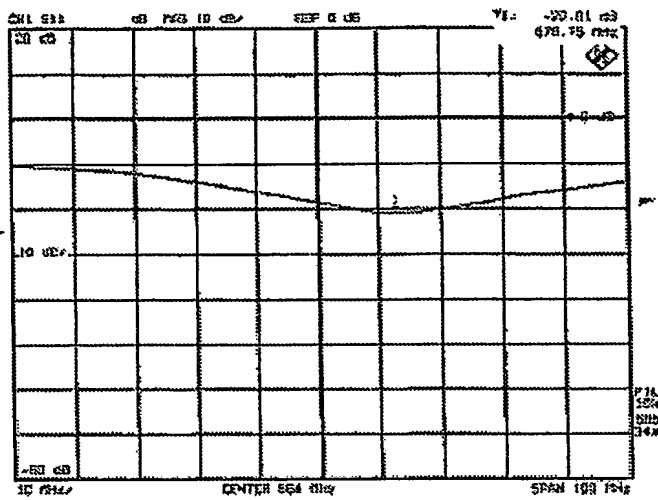
Antenna 2: return loss measured on W2 coupling conductor

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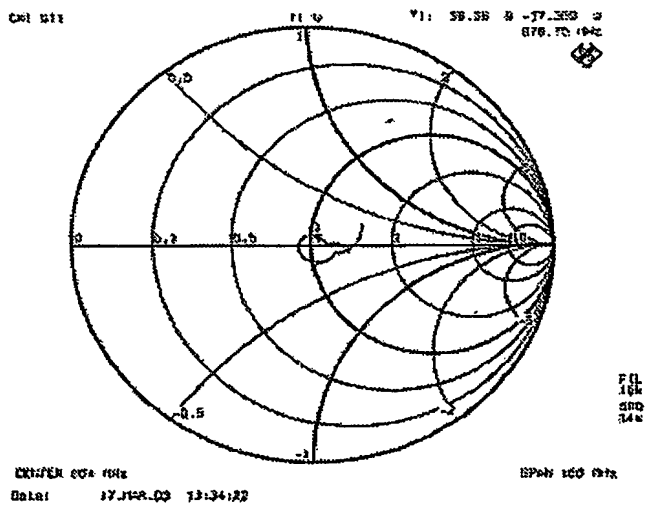
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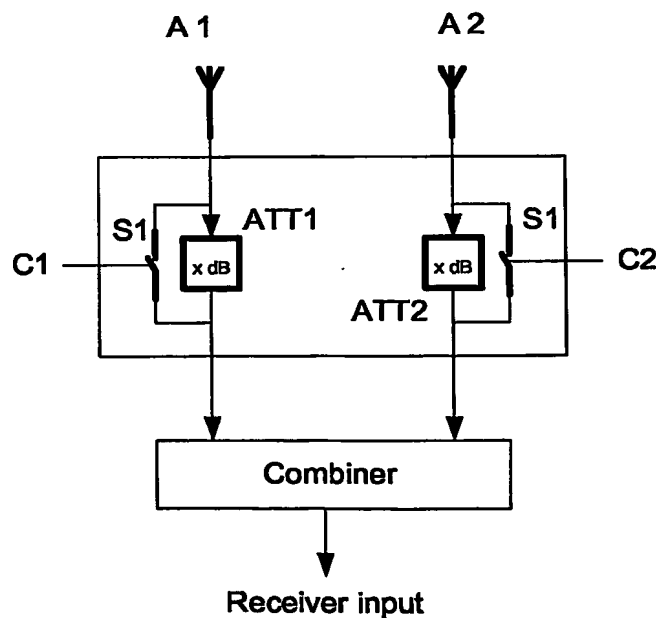
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Antenna 2: measured input impedance on W2 coupling conductor



It is well known that antenna diversity will help to reduce multipath problems in an indoor environment. One of the major problems is that first the output signal has to have errors or distortion before some decision can be made to change polarity, position or gain of the antenna. With this antenna arrangement it is possible to resist in a high degree to the average moderate flat fading drops without switching to another antenna situation and creating audible effects. In this in-home wireless audio distribution unit, the average signal drops of the received signal strength is found to be around 10 db. The antenna arrangement is operating in two modes. The first mode is resolving the most frequent average signal drops without switching to another uncorrelated antenna. The second mode is resolving for the less often large signal dips. The second mode is also used for improving the large signal handling of the receiver since in this application the receiver can be physically close to the transmitter. This arrangement will lead to less dropouts and less distortion for the customer. Practical tests have shown a major increase in reliability of the wireless audio link.



The antenna arrangement exists of two uncorrelated antennas. For example in an indoor wireless headphone system A1 and A2 are electrical antennas in parallel with the head separated  $\lambda/4$ . Control signals C1 and C2 are correlated and have two positions; S1 open/ S2 closed and S1 closed/S2 open.

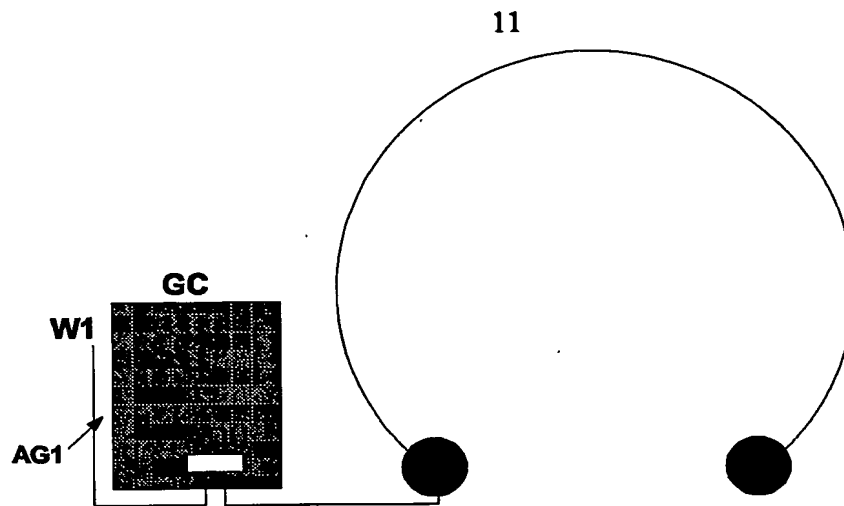
In the first mode, one antenna (for example A1) is connected with the combiner. Antenna (A2) is first attenuated and connected with the combiner. Antenna (A2) is x db attenuated. For example in a wireless indoor audio headphone system this can be in the order of 10 db.

- 5 The combined signals are fed to the receiver input. Antenna (A1) is receiving nominal indoor signals while antenna A2 is receiving nominal indoor signals uncorrelated to antenna (A1). The combined signal can be lower than if only antenna (A1) is used because both antennas are uncorrelated. However this combined signal is only slightly reduced against the performance of only one antenna. The advantage of this first mode is during the event of flat
- 10 fading. If the signal suddenly drops on antenna (A1) to a level that is below the receive threshold, antenna (A2) is still receiving signals since the antenna is uncorrelated. This signal is attenuated by some db (for example 10 db) and has enough energy above the receiver threshold level. There are no audible effects. In case the received signal is too weak for this antenna mode due to a deep flat fading condition, the DSP unit will steer the arrangement in
- 15 the second mode. In practice this happens less often.

- In the second mode the antenna configuration is controlled in such a way that the other antenna (A2) is switched through to the combiner while in the un-attenuated antenna (A1) the attenuator is switched in. In this situation antenna (A2) the full-received signal is now connected via the combiner to the receiver and the arrangement has switched to another
- 20 physical position. In this mode audible effects can occur.

- Another effective antenna arrangement is the combination of the first described antenna arrangement with coupling wire W1 but without the second coupling wire W2. As second antenna in the diversity system the metal headband from a headphone is used as antenna. The
- 25 metal headband is above the users head and for a large length in a horizontal position. This makes that this antenna arrangement consists out of a magnetic- and electric sensitive antenna while the electric sensitive antenna (headband) is merely horizontal polarised. This two factors makes that there is no correlation between the two antenna constructions. In the high quality headphones this metal headband is necessary for acoustic reasons and in this
- 30 way the headband antenna is besides the electrically performance as antenna also a low cost solution.

The headband can be tuned with a tuning network to be resonant at the wanted receive frequency. It has been found by measurements that this kind of construction gives an antenna



that is usable over a wide frequency range. Since this is a wideband antenna detuning from the near of the users head has not much effect on received signal strength.

**CLAIMS:**

1. An antenna arrangement for receiving radio frequency signals, the antenna arrangement comprising a ground conductor plane (GC) and a thereto coupled conductor (W1), the coupled conductor (W1) being arranged substantially in a same plane as the ground conductor plane (GC) and being separated therefrom (GC) by an air gap (AG1).

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2. The antenna arrangement according to claim 1, wherein the coupled conductor (W1) comprises a coupling wire (W1).

3. A headphone comprising an antenna arrangement according to claim 1 or 2.

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